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(21) International Application Number: PCT/NL99/00507 (22) International Filing Date: 9 August 1999 (09.08.99) (30) Priority Data: 1009841 11 August 1998 (11.08.98) NL (71) Applicant (for all designated States except US): DSM N.V. [NL/NL]; Het Overloon 1, NL-6411 TE Heerlen (NL). (72) Inventors; and (75) Inventors/Applicants (for US only): BELT, Johannus, Wilhelmus [NL/NL]; Spaans Neerbeek 23, NL-6164 CH Geleen (NL). VERMEULEN, Jacobus, Adriaan, Antonius [NL/NL]; Skimmiastraat 21, NL-6163 MH Geleen (NL). KÖSTERMANN, Mike [DE/NL]; Wezelstraat 27, NL-5854 JA Nieuw-Bergen (NL). (74) Agent: DORRESTIJN, Antoon; Octrooibureau DSM, P.O. Box 9, NL-6160 MA Geleen (NL).		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i>
(54) Title: PROCESS FOR HYDROGENATION OF CARBON-CARBON DOUBLE BONDS OF AN UNSATURATED POLYMER (57) Abstract The invention relates to a process for hydrogenating carbon-carbon double bonds of an unsaturated polymer by adding to the unsaturated polymer (1) a reducing agent selected from the group comprising hydrazines and hydrazine-releasing compounds, (2) an oxidising compound and (3) a catalyst, wherein the catalyst contains an element from group 13 of the Periodic Table of the Elements.		

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5 PROCESS FOR HYDROGENATION OF CARBON-CARBON DOUBLE BONDS
 OF AN UNSATURATED POLYMER

 The invention relates to a process for
hydrogenating carbon-carbon double bonds of an
10 unsaturated polymer by adding to the unsaturated
polymer (1) a reducing agent selected from the group
comprising hydrazines and hydrazine-releasing
compounds, (2) an oxidising compound and (3) a
catalyst.

15 A similar process is known from US
4,452,950. This patent discloses that the reduction of
carbon-carbon double bonds of an unsaturated polymer,
with the polymer having been brought into the latex
form, is carried out in the presence of a metal ion
20 initiator. The metal ion initiator is a metal compound
that reacts with hydrazine and is reduced by the
hydrazine to a lower valence state. Examples of
suitable metal ion initiators are Cu and Fe sulphates.
After all reactants are added, the mixture is heated to
25 the reflux temperature of the reaction mixture.

 A drawback of this process is that the
polymer is crosslinked early in the hydrogenation
process and that heavy metals are left behind in the
polymer after it is worked up.

30 The present invention aims to eliminate
these drawbacks.

 To that end, the invention provides a

process in which the catalyst contains an element from group 13 of the Periodic Table of the Elements.

The Periodic Table of the Elements as used in the present application is published on the inside
5 of the cover of the Handbook of Chemistry and Physics, 67th edition, 1986-1987 in accordance with the latest IUPAC nomenclature.

Furthermore, the process of the present invention presents the advantage that the reducing
10 agent and oxidising compound may be present in equimolar amounts to at the most a minor excess relative to the double bonds of the unsaturated polymer to be reduced.

Also, the reaction is catalysed so well
15 that a heating step may be omitted so that the hydrogenation process is much simplified.

Crosslinking of the latex during the hydrogenation process as described in US 4,452,950 is mentioned in US 5,039,737 and US 5,442,009. Both
20 Patents disclose a process for breaking up the gel structures through post-treatment with ozone.

From application WO 91-A-06579 it is known to carry out a hydrogenation in the absence of a catalyst. However, this process employs a high
25 hydrazine-to-unsaturated-polymer molar ratio in order to obtain a non-crosslinked polymer. Excess hydrazine subsequently needs to be worked up and destroyed, which from an economics point of view is costly and from an environmental point of view is unacceptable.

30 The unsaturated polymers that can be hydrogenated via the process of the present invention

are composed of 5-100% by weight of a conjugated diene-monomer unit and 95-0% by weight of a vinyl-unsaturated monomer unit. Specific examples of conjugated diene-monomer units are 1,3-butadiene, 2,3-dimethyl
5 butadiene, isoprene and 1,3-pentadiene. Specific examples of vinyl-unsaturated monomer units are nitriles (for example acrylonitrile and methacrylonitrile), vinyl aromatic hydrocarbons (for example styrene, (o-, m-, p-) alkylstyrenes and
10 divinylbenzene) dialkenyl aromatics (for example diisopropenyl benzene), unsaturated carboxylic acids and esters thereof (for example acrylic acid, methacrylic acid, crotonic acid, itaconic acid, maleic acid, methyl acrylate, ethyl acrylate, butyl acrylate,
15 2-ethylhexyl acrylate and methyl methacrylate), vinylpyridine and vinyl esters (for example vinyl acetate).

The unsaturated polymers may be prepared in different manners for example through emulsion
20 polymerisation, solution polymerisation and bulk polymerisation.

Specific examples of suitable unsaturated polymers are polybutadiene, polyisoprene, styrene-butadiene copolymers (SBR), acrylonitrile-butadiene
25 copolymers (NBR), natural rubber, butadiene-isoprene rubber and terpolymers of butadiene, acrylonitrile and butylacrylate or acrylic acid.

Most preferably NBR is used.

The unsaturated polymers hydrogenated via
30 the process of the present invention are characterised in that their backbone chain contains carbon-carbon

double bonds that have an adverse effect on the polymer's thermal, photochemical and oxidative stability.

During the hydrogenation, the unsaturated
5 polymers preferably are present in the latex form. The latex form is an aqueous emulsion of polymer, in which sundry additives for example soap and stabilisers may be present. A description of the latex form which is suitable for the hydrogenation of unsaturated polymers
10 via the process of the invention is given in for example US 5,442,009.

The latex of the unsaturated polymer may be hydrogenated as such. The polymer concentration in the latex is in the range of from 1 to 70% by weight,
15 preferably between 5 and 40 %wt.

The reducing agent is selected from the group comprising hydrazines and hydrazine-releasing compounds for example hydrazine hydrates, hydrazine acetate, hydrazine sulphate and hydrazine
20 hydrochloride. If the unsaturated polymer is hydrogenated in latex, use is preferably made of hydrazine and hydrazine hydrate. Alternative hydrazine sources may be used if hydrogenation is effected in solution or in the melt and if the alternative
25 hydrazine sources do not adversely effect the stability of the latex.

Latices formed from, for example, non-ionic soaps may be used in combination with hydrazine, hydrazine hydrate, hydrazine hydrochloride and
30 hydrazine sulphate.

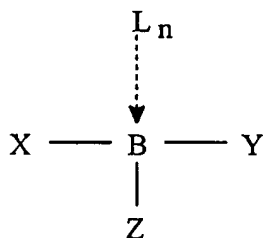
The hydrazine or hydrazine releasing

compound preferably is present in a molar ratio of from 0.1:1 to 100:1 relative to these carbon-carbon double bonds. Preferably, this ratio lies between 0.8:1 and 5:1, most preferably between 0.9:1 and 2:1.

5 Oxidising compounds that are suitable for the process of the invention are for example air, oxygen, ozone, peroxides, hydroperoxides, iodine, iodates, hypochlorite and similar compounds. Particularly suitable oxidising compounds are selected
10 from the group consisting of peroxides and hydroperoxides. Most preferably, use is made of hydrogen peroxide.

 The oxidising compound is preferably present at a molar ratio of 0.1:1 to 100:1 relative to
15 the carbon-carbon double bonds. More preferably, this ratio is between 0.8:1 and 5:1, most preferably between 0.9:1 and 2:1.

 It is preferred for the catalyst be a compound which contains boron (B). Examples of
20 preferred B-containing catalysts are compounds of the general formula



25 where X, Y and Z are chosen independently of one another from the group comprising R, =O, OR, OOR, NR₂, SR, PR₂, OC(=O)R and halogen atoms, where R is a H atom

or an alkyl, aryl or cycloalkyl group having 1-20 carbon atoms, or a hydrocarbon group having 1-20 C atoms and containing a heteroatom from groups 14, 15, 16 and 17 of the Periodic Table of the Elements, or a polymerchain containing one or more polar groups; wherein X and Z and optionally Y may form a bridge; L is an electron-donating ligand, which may be bonded to either X, Y or Z; $n = 0, 1$ or 2 .

Examples of suitable electron-donating ligands are for example water, an alcohol, pyridine, bipyridine, triazine, pyrrole compound, an imidazole compound, a pyrazole compound, a pyrimidine compound and a pyrazine compound, an ester, ether, a furan, tetrahydrofuran, pyrans, dioxan, phosphine, phosphide, phosphate, a thio compound or a polymer, for example a polyvinylalcohol or polyethyleneoxide.

Salts of abovementioned boron-containing compounds might also be applied.

Preferably L is chosen from the group comprising diols, polyvinylalcohols and polyethyleneoxide.

It is preferred for the catalyst to be chosen from the group consisting of borates, peroxiborates and boric acid (H_3BO_3). More preferably, the catalyst is boric acid. It is most preferred that boric acid is used in combination with a polyvinylalcohol.

The catalyst of the present invention may be combined with the oxidising compound so that less or no oxidising compound needs to be added separately. An example of a catalyst that also has an oxidising effect

is peroxiborate.

Another preferred embodiment of the present invention is addition of boric acid to the reaction mixture together with the peroxide or hydroperoxide.

5 The molar ratio of the catalyst to the carbon-carbon double bonds of the unsaturated polymer is between 1:1000 and 10:1. The ratio preferably is between 1:50 and 1:2.

 The order in which the compounds are added
10 for the hydrogenation reaction may in principle be random. Preferably, however, the oxidising compound is added last and in such a way that the concentration of the oxidising compound remains low during the hydrogenation reaction.

15 The degree of hydrogenation is the percentage of carbon-carbon double bonds that is saturated after the hydrogenation reaction relative to the initial amount of double bonds. The process of the present invention provides polymers that as a rule
20 have a degree of hydrogenation higher than 60%. Preferably, the degree of hydrogenation is higher than 80%. The process is eminently suitable for preparing polymers having a degree of hydrogenation higher than 90%.

25 The hydrogenation reaction temperature normally is between 0° and 250°C. The temperature preferably is between 20° and 100°C. A reaction temperature between 40° and 80°C is particularly preferable. Most preferable is a reaction temperature
30 between 60 °C and 80 °C, which results in a high catalyst activity, so that low catalyst concentrations

can be used.

During hydrogenation in a latex, a minor amount of solvent for the unsaturated polymer may be present. In that case, the amount of solvent may vary
5 between 0 and 20%wt (solvent relative to polymer).

The hydrogenation time normally is between 30 minute and 24 hours. The hydrogenation time preferably is between 1 hour and 12 hours.

The process is illustrated by the following
10 examples without being limited thereto.

In almost all cases the degree of hydrogenation was determined with the aid of ^1H -NMR in a Bruker 200 MHz instrument. The measurement was conducted on polymer precipitated in isopropanol, that
15 was after precipitation dried with filter paper and immediately dissolved in deuterated chloroform. The degree of hydrogenation was calculated from the ratio of the integrals of the olefinic protons, which are between 5.2 and 5.6 ppm, and the proton adjacent to the
20 nitrile group, being between 2.35 and 2.65 ppm.

In some cases (expressly indicated) the degree of hydrogenation was determined by Raman spectroscopy (using a Spectrum 2000 NIR FT Raman instrument).

25 The C=C stretch vibrations of the vinyl, cis and trans bonds can be seen in the Raman spectrum between 1600 and 1700 cm^{-1} . The C \equiv N stretch vibration can be seen at 2240 cm^{-1} . The peak height ratio between the C=C stretch and the C \equiv N stretch relative to the
30 blank was used for determining the degree of hydrogenation, it being assumed that the stretch

vibration of the nitrile group does not change significantly as a result of the unsaturated polymer being hydrogenated.

5 Example 1

A solution of 0.68g of H_3BO_3 (11 mmoles) and 6.31 g of $N_2H_4 \cdot 1H_2O$ (hydrazine monohydrate, 126 mmoles) in 5.5g of water were added to a 250-ml glass three-neck flask equipped with a glass top stirrer, cooler and peristaltic pump and containing 25g of latex, Nysin® 33/3 (a copolymer of 67% butadiene with 33% acrylonitrile) with a polymer content of 25% and containing a total of 77.5 mmoles of carbon-carbon double bonds. A few drops of silicone oil were added as defoamer.

The latex was heated to 40°C and stirred for some minutes. While the contents were being stirred, 13.30 g of a 30% solution of H_2O_2 in water (117 mmoles) were added drop-wise during a period of 6 hours with the aid of the peristaltic pump. On being hydrogenated, the 5 grams of latex were poured into 50 grams of isopropanol. The polymer dissolved completely in chloroform (no gel particles were visible). The degree of hydrogenation, determined by 1H -NMR, was 96%.

25

Example 2

Example I was repeated except that the amount of hydrazine was varied as shown in Table 1. The H_2O_2 was added drop-wise in an equimolar amount relative to hydrazine. All samples dissolved completely in chloroform (no gel

30

particles were visible).

Ex.	Hydrazine monohydrate (grams)	H ₂ N-NH ₂ .H ₂ O equivalents relative to C=C	Degree of hydrogenation (%)
II.1	3.1	0.8	70
II.2	3.9	1.0	85
II.3	4.3	1.1	89
II.4	4.7	1.2	93
I	6.31	1.6	96

Table 1. Degree of hydrogenation as a function of the
5 amount of hydrazine.

Example III

Example I was repeated except that the H₂O₂
10 was added in 12 hours, with two different amounts of hydrazine. Slow addition of hydrogenperoxide gives an increase in the degree of hydrogenation.
All samples dissolved completely in chloroform (no gel particles visible).

15

Ex.	Hydrazine monohydrate (grams)	H ₂ N-NH ₂ .H ₂ O equivalents relative to C=C	time (hours)	Degree of hydrogenation (%)
III.1	3.9	1.0	12	87
III.2	4.7	1.2	12	97

Table 2. Degree of hydrogenation at 12 hours of reaction time and variable amount of hydrazine.

Example IV

5 Example I was repeated except that 4.68 grams of $N_2H_4 \cdot 1H_2O$ (hydrazine monohydrate) and 0.16 grams of boric acid were added, and the reaction was carried out at different temperatures. Low amounts of hydrazine monohydrate and boric acid give a lower
10 degree of hydrogenation. The degree of hydrogenation is increased by raising the temperature of the reaction. All samples dissolved in chloroform.

Ex	Temperature (°C)	Degree of hydrogenation (%)
IV.1	40	60
IV.2	70	90

15 Table 3. Degree of hydrogenation as a function of temperature

Example V

20 Example I was repeated except that the amount of boric acid was varied. Increase of the amount of boric acid, gives an increase in the degree of hydrogenation. All samples dissolved completely in chloroform (no gel particles visible).

Ex.	Boric acid (grams)	Degree of hydrogenation (%)
V.1	0	60
V.2	0.17	80
V.3	0.34	85
V.4	0.51	96
V.5	0.85	93

Table 4. Degree of hydrogenation as a function amount of boric acid added.

5

Example VI

Example IV.1 was repeated, except that boric acid was dissolved in the hydrogenperoxide solution, and added to the latex together with the hydrogenperoxide.

10

The degree of hydrogenation increased considerably upon premixing of boric acid with the hydrogenperoxide.

Ex	Boric acid premixed with H_2O_2	Degree of hydrogenation (%)
IV.1	no	60
VI.1	yes	91

15 Table 5. Effect of premixing of boric acid with hydrogenperoxide.

Example VII

Example IV.1 was repeated, except that ligands L were added to the latex with the boric acid. Addition of ligands increases the catalytic activity of
5 boric acid.

Ex.	Ligand L	gram	Degree of hydrogenation (%)
IV.1	no	--	60
VII.1	ethanol	0.12	70
VII.2	1-phenyl-1,2-ethanediol	0.34	70
VII.3	polyethyleneglycol, OH-terminated, Mw 35.000	0.15	83
VII.4	polyvinylalcohol, 98% hydrolysed, Mw 20.000	0.15	93

Table 6. Addition of ligands L to the reaction mixture.

10

Comparative experiment A

An amount of $N_2H_4 \cdot 1H_2O$ (hydrazine monohydrate), as shown in Table 1, dissolved in 5.5 grams of water, were added to a 250-ml glass three-neck
15 flask equipped with a glass top stirrer, cooler and peristaltic pump and charged with 25g of latex, Nysin 33/3 with a polymer content of 25%. A few drops of silicone oil were added as defoamer.

-The hydrogenation reaction was carried out as in
20 Example I, with H_2O_2 in a 30% solution of H_2O_2 in water being added drop-wise with the aid of the peristaltic

pump in an equimolar amount relative to hydrazine.

All samples dissolved completely in chloroform (no gel particles were visible).

Comp. ex.	Hydrazine monohydrate (grams)	H ₂ N-NH ₂ .H ₂ O equivalents relative to C=C	Degree of hydrogenation (%)
A.1	3.9	1.0	55
A.2	5.9	1.5	67
A.3	7.6	2.0	80
A.4	9.8	2.5	94

5

Table 7. Degree of hydrogenation as a function of the amount of hydrazine required in the absence of boric acid

10 Comparative experiment B

4.3 g of N₂H₄.1H₂O (hydrazine monohydrate, 1.1 equivalent relative to C=C), followed by 0.0018 grams of CuSO₄.5H₂O in 5 grams of water were added to a 250-ml glass three-neck flask equipped with a glass top stirrer, cooler and peristaltic pump and charged with 25g of latex, Nysin 33/3 with a polymer content of 25%. A few drops of silicone oil were added as defoamer. The latex was heated to 40 °C and stirred for some minutes. While the contents were being stirred, 10 g of a 30% solution of H₂O₂ in water were added drop-wise with the aid of the peristaltic pump. During the hydrogenation, 1-gram latex samples were taken and

20

these were precipitated in 10 grams of isopropanol. The polymer's solubility was directly measured visually in chloroform.

Ex.	H ₂ O ₂ added (%)	Degree of hydrogenation (%) ^{x2}	Solubility
B.1	13.9	14	soluble
B.2	33	28	soluble
B.3	47	-	gelled
A.4	100	71	gelled

5

Table 8. Solubility as a function of H₂O₂ added and degree of hydrogenation

The polymers in Experiments B.3 and B.4 were subjected to a Soxhlet extraction with chloroform, with the aid of which the gel content was determined. The sample in Experiment B.3 contained 70% gel and the sample in Experiment B.4 contained more than 90%. The degree of hydrogenation in Experiment B.4 was determined by Raman spectrometry.

Comparative example C

5.8 g of N₂H₄·1H₂O (hydrazine monohydrate, 1.5 equivalent relative to C=C), followed by an amount of CuSO₄·5H₂O as indicated in Table 7 in 5 gram of water were added to 250-ml glass three-neck flask equipped with a glass top stirrer, cooler and peristaltic pump and charged with 25g of latex, Nysin 33/3 with a polymer content of 25%.

The latex was heated to 50 °C and stirred for some minutes. While the contents were being stirred, 13.1 g of a 30% solution of H₂O₂ in water were added drop-wise with the aid of the peristaltic pump. After the
5 hydrogenation, 1-gram latex samples were taken and these were precipitated in 10 grams of isopropanol. The polymer's solubility was directly measured visually in chloroform (see Table 7).

10

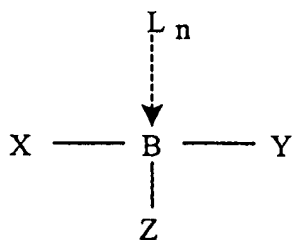
Comp. ex.	CuSO ₄ .5H ₂ O (grams)	Degree of hydrogenation (%) ^{x1}	Solubility
C.1	0.0009	80	gelled
C.2	0.0019	89	gelled
C.3	0.0095	55	gelled
C.4	0.017	32	gelled

Table 9. Solubility as a function of degree of hydrogenation

15 The polymer obtained in each experiment was subjected to a Soxhlet extraction with chloroform. The gel content was found to be higher than 60% in all cases. The degree of hydrogenation of the samples in Comparative Example C was determined by Raman
20 spectrometry.

CLAIMS

1. Process for hydrogenating carbon-carbon double
5 bonds of an unsaturated polymer by adding to the
unsaturated polymer (1) a reducing agent selected
from the group comprising hydrazines and
hydrazine-releasing compounds, (2) an oxidising
compound and (3) a catalyst, characterised in
10 that the catalyst contains an element from group
13 of the Periodic Table of the Elements.
2. Process according to Claim 1, characterised in
that the catalyst is a compound which contains
boron.
- 15 3. Process according to Claim 2, characterised in
that the catalyst is a compound of the general
formula



20

- wherein X, Y and Z are chosen independently of
one another from the group comprising R, =O, OR,
OOR, NR₂, SR, PR₂, OC(=O)R and halogen atoms,
where R is a H atom or an alkyl, aryl or
25 cycloalkyl group having 1-20 carbon atoms, or a
hydrocarbon group having 1-20 C atoms and
containing a heteroatom from groups 14, 15, 16

and 17 of the Periodic Table of the Elements, or a polymerchain containing one or more polar groups; wherein X and Z and optionally Y may form a bridge;

5 L is an electron-donating ligand, which may be bonded to either X, Y or Z;

n = 0, 1 or 2.

4. Process according to Claim 3, characterised in that the catalyst is boric acid.

10 5. Process according to Claim 4, characterised in that boric acid is used in combination with a polyvinylalcohol.

6. Process according to anyone of claims 1-5, characterized in that the molar ratio of the catalyst to the carbon-carbon double bonds of the
15 unsaturated polymer is between 1:50 and 1:2.

7. Process according to anyone of claims 1-6, characterized in that the oxidising compound is selected from the group consisting of peroxides and hydroperoxides.
20

8. Process according to anyone of Claims 4-7, characterised in that the boric acid is added to the reaction mixture together with the peroxide or hydroperoxide.

25 9. Process according to Claim 7, characterised in that the oxidising agent is hydrogen peroxide.

10. Process according to anyone of Claims 1-9, characterised in that the molar ratio of oxidising compound to carbon-carbon double bonds
30 is between 0.9:1 and 2:1.

11. Process according to any one of Claims 1-10,

characterised in that the molar ratio of hydrazine or hydrazine releasing compound to carbon-carbon double bonds is between 0.9:1 and 2:1.

- 5 12. Process according to any one of Claims 1-11,
characterised in that the reducing agent is
selected from the group consisting of hydrazine
and hydrazine hydrates.
- 10 13. Process according to any one of Claims 1-12,
characterised in that the unsaturated polymer is
present in the latex form.

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/NL 99/00507

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C08F8/04 C08C19/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C08F C08C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 452 950 A (L. G. WIDEMAN) 5 June 1984 (1984-06-05) cited in the application column 3, line 27 -column 4, line 9; claims 1-15 ---	1-13
Y	EP 0 801 079 A (SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ B.V.) 15 October 1997 (1997-10-15) page 3, line 52 -page 4, line 26; claims 1-14 ---	1-13
Y	DE 35 20 103 A (BASF AG) 11 December 1986 (1986-12-11) page 3, line 32 -page 4, line 28; claims 1,2; examples 1-4 ---	1-13
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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INTERNATIONAL SEARCH REPORT

International Application No.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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